

A Service-oriented Approach towards Context-aware Mobile Learning Management Systems

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Abstract—Thanks to the public and low cost availability of wireless high speed internet access students are increasingly equipped with mobile internet enabled devices to connect to university services like Learning Management System (LMS). But the applications services like LMS are still unable to adapt themselves to modern mobile devices with restrictions like reduced display size. By recognizing the device and its restrictions it is possible to optimize the LMS interface. Additionally by using device features like position, acceleration sensors, or the camera it is possible to detect the intentions of the user. The context of the user's situation determines which university services are helpful and interesting. Gathering these context information and reasoning on them is the foundation of our context- and service-oriented approach towards a mobile LMS. This enables us to personalize the mobile learning experience with location-sensitive lecture streaming, campus navigation, and ubiquitous features of the whole university computing infrastructure. By using a service-oriented architecture we are able to compose a variety of different university and external services towards a pervasive university.

Keywords-context-aware computing, service-oriented architecture, mobile computing, elearning, learn management system

I. MOTIVATION

Mobile internet enabled devices are heading into the center of the student society. Nearly every currently sold phone is able to use internet services via networks like GRPS, UMTS, or HSDPA. Devices like Apple's iPhone and Android-based systems increased the popularity of smartphones for private users. But services important to students like university services are not considering the various restrictions of these new devices. Figure 1 illustrates an unadapted LMS interface on a mobile device, here the iPhone. The user is technically able to use the LMS, but the usability is very restricted. Mobile devices provide different user interfaces like touchscreens or keyboards. Some devices are designed to be used with a stylus pen, others are controlled with the bare finger. Moreover, device-specific screen sizes and resolutions require adapted graphical user interfaces. Besides the restrictions of mobile internet enabled devices there are unused features provided by these devices. FPS can be combined with acceleration sensors to determine the users



Figure 1. iPhone showing the unadapted user experience of Stud.IP

field of view. Built-in cameras and the ability to render three-dimensional objects in real-time allow the visualization of learning contents in a memorable way [1].

An adaption to the restrictions and the usage of device-specific features provide support for various ubiquitous and pervasive eLearning scenarios [2][3]. By knowing where the user currently is located and what is next on his timetable possible intentions can be determined.

This can enhance the learning experience by providing video or audio lectures while using local traffic, guiding the way to books recommended by the lecturer in the library, or just by accessing the lecture notes in a device optimized data format while sitting in the auditorium [4]. For

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realizations of these examples a simple and universal access to context information, like the device capabilities, is needed. Besides this, the information that is already within the LMS needs to be analyzed for context information. Web services and service-oriented architectures offer a standardized and effective way to achieve interoperability between systems like the LMS and a context provider or consumer.

This paper gives a service-oriented approach to use collected information out of the LMS and sensed data from the mobile device towards a context-aware mobile LMS.

II. BASIC CONCEPTS

For a better understanding of the presented eLearning scenarios the basic concepts of learning management systems, context, and service-oriented architectures are illustrated in the following.

A *learning management system* (LMS) is a web-based software application that provides access to lecture notes and other course relevant features. They can be used to pass whole courses online, including live chats with tutors, online exams, and collaboration with other students [5]. In supporting the face-to-face learning paradigm they allow file upload for lecturers and students, wikis, and course enrollment.

Context is defined as *any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.*[6] So we understand context as description of the students' current situation, which is characterized by their identity, the device they are using to access the LMS, the courses they are registered to, where they are at the moment, and any information relevant to these aspects.

Service-oriented architecture (SOA) is an organizational paradigm for distributed computing [7]. While in client-server approaches a client needs to know the interfaces and addresses of all servers providing the required functionality, a client using a SOA only needs to know a single broker address and what functionality he needs. The consumer contacts the broker, where different service provider have published their functionalities as services. The response of the broker contains the interfaces and the addresses of the services which fit best to the consumers request. Now the consumer is able to use the service he considers to be the best or to make an other request. So a SOA provides dynamic universal access to different functionalities boxed in services.

III. CONTEXT-AWARE eLEARNING SCENARIOS

The purpose of the following scenarios is to expand, enrich and to facilitate the eLearning paradigm in the context of mobile context-aware blended learning. Blended learning is based on the alternation of face-to-face and online lectures, which can be recorded lectures that are provided by an LMS.



Figure 2. Interconnection of classroom and virtual world

The main advantage of multimedia enhanced learning is the overcoming of existing limits in the learning experience. Schulmeister points out four limits: the place, time, analog-digital, and standard limits that restrict the learning process [5]. Approaching these with a mobile context-aware LMS allows to provide more efficient, personalized and situation-optimized learning material and methods. To illustrate this statement the following eLearning scenarios are proposed, each focusing one limit.

A. Location-aware Learning

The approach for the place limit is to integrate the location into the learning process. With his mobile internet enabled device the student is able to connect to the LMS from everywhere. Additionally, the content can not only be adjusted to the restrictions of his environment, it can be related to his actual position. Information can be associated with locations and areas to extend excursions with up-to-date content. This includes, for example, information about the current position of relevant objects - like a book in the library, an upcoming TV report about the topic of a course, or an interesting exhibit in a museum that is tagged with the keyword from the last lecture. Services like this are chosen in the context of time and the student's location. On the other side, the application is able to react to real live restrictions like bandwidth with the recommendation of a different media format or buffering.

B. Pervasive Course Participation

The time limit, actually bounded to the time in front of a desktop computer, gets enlarged to the whole day a student has his smartphone with him. He is able to watch the recorded stream of his last lecture while he gets to the campus by train or to listen to it while he walks through the building to the room. This happens because the system recognizes he is not attending a lecture in person so he probably is interested in post- or preprocessing of the last

or next lectures in an adequate way. By knowing his device the system is able to provide a stream adapted to the display restrictions and multimedia features of the device.

After the course he is able to replay single parts of the lecture in preparation of his exams. The service-orientation and context-awareness of the used system is efficient because it knows, that soon there are exams and by accessing the LMS the students intention might be the postprocessing of specially tagged lectures.

C. Ambient Learning

The analog-digital limit can be approached by connecting physical objects with digital information like pictures and 3D-models. Augmented reality is just one aspect of connecting analog medias with the possibilities of the digital world, which means the mobile device detects marks and downloads related content for a visualization. This can be used to display 3D images of objects like historic buildings on the device. Other developments take the position and acceleration sensors of the device and estimate what is visible to the user according to his current position. This allows to illustrate historic sites just in the angle the user would have seen them 200 years ago from his position right on his device in the camera view. An example of the interconnection of virtual environments and physical classrooms is illustrated in figure 2. Here the virtual world of Second Life was integrated into a real classroom to enrich the learning experience [3]. Also information about architectural style, astronomic constellations or geographic conditions can be visualized.

While these applications are separate today, service-orientation and context-awareness can merge them in the future.

D. Device-optimized Learning

The last scenario tackles the standard limit, which points out that different standards lead to incompatibility. With every new device and application connected to the internet a new set of restrictions and possibilities is introduced. Beyond PDAs and smartphones, navigation, or entertainment systems might provide context and access to LMSs. Generic profiles which are created at runtime or are provided as context would allow individualized access better than a standard solution based on the least common denominator. By the concept of not adapting every service to every device, but to get to know the devices, capabilities and offering the usable services in a universal way we are able to combine already existing content with the features of current and upcoming devices. This requires this it is necessary to implement a software on the device which on one hand accesses the device specific sensors to provide their information as context and on the other hand offers an interface to the user which adapts itself to the device and the content that is presented.

IV. RELATED WORK

The Mobile Learning Engine (MLE) [8] is one possibility to interconnect an existing LMS (Moodle [9]) and mobile devices. The content must be customized previously. The plug-in for Moodle offered by the MLE is able to import the content of Moodle courses including exams. By offering a server side application the user is also able to consume Moodle content just with his mobile browser. By using Moodle, the system is focusing on a single LMS, so content of other systems is unavailable. Also the context-awareness is only achieved by a dedicated client, so new or actualized system features require a software update on every client. Another approach is to reduce the conventional three-framed design down to one frame but this did not maintain all functions of Moodle [10]. A device-specific customization was not focused.

A work [11] close to our intention is focused on an abstract layer to connect contextual information and external services. The contextual information is made accessible to context-aware applications, but reasoning on the context needs to be realized by them. We intend to provide a system that offers the context and conclusions as services to be consumed and combined. The focus on the Moodle LMS is noticeable and also the direct interaction with the LMS. The foreseeable development of the mobile devices is an harmonization of their abilities in using the internet and web applications, so a less device specific way leads to a broader target group.

V. SERVICE-ORIENTED CONTEXT-AWARENESS IN LMS

The application of our context definition towards the subject of mobile eLearning shows the relevance of data that can be sensed best by the mobile device. This includes information about the user like identity and position. His courses and personal as well as institutional university related data can be found in the LMS. These context sources are suitable to coarsely characterize the situation of a user. Therefore, the data needs to be gathered, stored, and interpreted in a flexible and extendable way, because new context sources like smart meeting rooms or home automation systems might also be integrated in the future.

The first part of such a system is a data model for context where different kinds of context can be managed. A fact-oriented approach in association with a knowledge-based system (KBS) covers the model and the storage, because the gathered data is not complex and the system provides relational representation and grammar for high-level context abstractions [12]. The access needs to be scalable in order to face situations where a lot of information needs to be stored and/or retrieved. To achieve this, a message-oriented middleware creates platform and programming language independent access. The KBS is filled with data via messages containing only the objects to be inserted or updated. These objects abstract the information of the real world to their

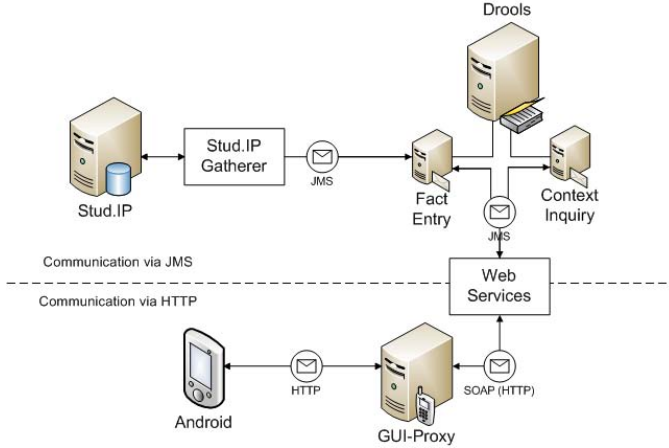


Figure 3. Architecture of the proposed system

context. User information includes facts like the name, user name, and email, while the device information includes the type, owner and position. Essential to the usage of this system for context is the ability to establish relations between objects and the reasoning on them. KBSs realize this with rules and queries.

A very easy rule might look like this *"IF user has a lecture now AND user is not on the campus THEN inform user via personal message including link to the live stream"*. To realize this, the system needs to know the current position of the user, his courses and the location where he should be at that time. This information can all be processed out of the LMS and his mobile device. While a rule performs a specified action, a query returns data sets that matches given conditions. A simple example would be *query "absent students" (String course) person : Person(takenCourses contains course, location != course.room)* which would return all students of the course, who are not within the estimated room. To provide this context the queries can be mapped to web services which in turn can be aggregated with other services to offer higher functionality. To obtain the privacy of the user, there are already proven concepts like encryption and authentication for web service environments.

A. Overall Architecture of the Mobile LMS Prototype

In the realization of this system we used the Stud.IP LMS [13] as a starting point. Like Moodle it is open source but the focus is not only on providing the learning content, it focuses on organizing institutions, courses, and materials which is much closer to the relevant context of our purpose. In our system context is stored in a context server implemented with Drools [14], an open source rule-based system based on Java. This led to the usage of the Java Message Service (JMS) API for the message-oriented middleware (MOM). Other KBS like IBM WebSphere ILOG can also be used since we exploit only basic features of the KBS. For the

mobile device the Android operating system (OS) [15] was used, which is open-source and comes along with a sufficient development framework. It provides simple access to GPS and other device specific data. To connect the Android platform with the Drools context server and the Stud.IP LMS we use a HTTP-Proxy to receive the requests of the mobile device, to request the appropriate context, and to redirect the LMS interface to the mobile device in the most appropriate way. An overview is given in figure 3. In the following the technical realization is described more deeply.

B. Knowledge-Based Backend for the Learning Management System Stud.IP

Stud.IP is based on MySQL and PHP. The information containing the context is retrieved from the database very efficiently. This gathered information about the Stud.IP concepts like users, courses, lectures, and rooms is transformed into serializable objects. These objects represent entities and contain all their static information like course title or room number. External context, for instance the position of a mobile device, is also handled within serializable objects. The used context model with a divide into static and dynamic information relating to each other allows to store every relevant information in the KBS. After retrieving the information all appropriate rules of the KBS are fired and the connections between the entities are established, for instance the users and rooms get connected with the lectures. While the system is active it is looking for patterns to apply the rules on them. A rule used in the system is illustrated below.

```
rule "ConnectLecturesWithCourses "
when
  l : Lecture (isAssigned == false)
  c : Course ( c.lectures not contains l,
              l.StudIP_ID == c.StudIP_ID)
then
  l.setisAssigned(true);
  c.addLecture(l);
end
```

The first part of the rule checks if there is an unassigned lecture and a course with the same identification but without a link to the lecture. If this condition is fulfilled the lecture gets assigned to the course. This enables the system to connect recently added lectures to already existing courses. In this way also newly added information is set into context with already referenced information. For instance, a new device is immediately connected to its owner if he is already in the system, and if this device updates his position the location of the user is updated, too.

C. Service-oriented Context Access

To access the stored information it is necessary to know what objects are stored and what queries are possible. This needs to be in a platform independent way, because the context



Figure 4. QR-Tag coding room information

might be requested by a web site where PHP is the used scripting language, by a Firefox browser plug-in, or directly by the mobile device. To achieve this a service-oriented architecture with web services offers the most comfort. The accessible objects are serialized into XML which allows them to be machine and human readable, and the requests are SOAP messages via HTTP. The functionality to use this is supported by every system with the ability to send and receive data via a network. Web services provide queries in a generic way like *getCourseByDate(Date date)* or *getCourseByUsername(String username)* so complex queries can be easily aggregated by multiple queries. While doing this the web services provide the ability to ensure that the KBS in the background is not corrupted with too much requests. This is possible because the web services do not access the KBS directly, but they communicate with the KBS via a message-oriented middleware, which is monitoring the traffic and able to react on unusual usage with forwarding correct and rejecting suspicious requests. We used ActiveMQ [16], an open source messaging provider. If needed it is also possible to implement subsystems for more scalability with caching, triggers to create new web service instances, or replication of highly used parts of the KBS.

D. Mobile LMS access using context information

To reach the different mobile devices the system must be very basic and theoretically usable with every mobile internet enabled device, no matter which platform is used. So we decided to use a GUI-Proxy to be the access point of the mobile devices instead of the LMS itself. This proxy tries to identify the used platform and determines the optimal template for the device. This is completely independent of position, time or other context. To gain more context-awareness some software is needed on the device to send the coordinates and other device specific context to the GUI-Proxy. The implementation of these basic functionalities requires low effort and is independent from the view of the LMS which stays in the standard browser of the device. We used the android system for the prototype, but an implementation on the iPhone MacOS, palm WebOS or

other systems would be quite similar. While the user with no additional context information only gets an optimized template for his usage of the LMS, a user with more known context can access the LMS in a much more personalized way. This means the GUI-Proxy is able to determine the location of the user, so that he is able to differentiate if he is on the campus or not. A closer indoor locating is currently realized with QR-Tags which determine the room the user is in. Such a code is illustrated in figure 4. By knowing whose device is connecting to the proxy it can determine which course the owner is heading to and can give him fast navigation to the page of the next course where changes of the room or other important information would be accessible. This is illustrated in figure 5.



Figure 5. Choice between the link to the current or next lecture and a link to the closest local traffic stop considering the user's position

VI. SUMMARY AND FUTURE WORK

This article introduced the concept and a system for retrieving the context of a mobile learning scenario by means of services which allows simple and universal access to an LMS. Beside this the system is able to reason on the context and to provide not only the raw context data but also locations and other user specific information that can be read out of the data. The communication infrastructure with the coupling of a service-oriented architecture and a message-oriented middleware is scalable and expendable. By using open source software in every stage of the system the usage in the environment of a university is facilitated by

adjusting it to given or upcoming restrictions or possibilities. The next steps will include an implementation on the iPhone to evaluate the mobile usability and user acceptance. Results will indicate other approaches to improvements of the LMS and the GUI-Proxy. Also the usage of Wi-Fi and Bluetooth spots to determine the indoor position of the user without his interaction is planned. Moreover, a system for dynamic video and audio providing and an enhanced mobile control of multimedia technology like beamers, microphones, or the sun-blind is intended.

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